IIT JEE MAINS 2016 9TH APRIL 2016

PHYSICS

1. In the following 'I' refers to current and other symbols have their usual meaning. Choose the option that corresponds to the dimensions of electrical conductivity :

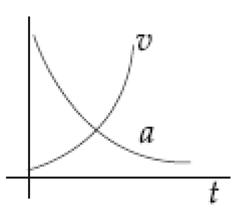
(1) $ML^{-3} T^{-3} I^2$

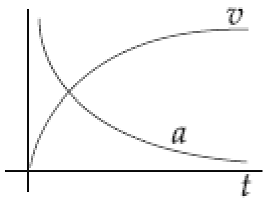
(2) $M^{-1} L^3 T^3 I$

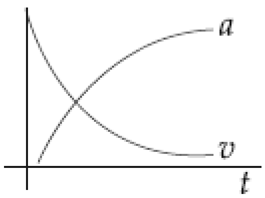
(3) $M^{-1} L^{-3} T^3 I^2$

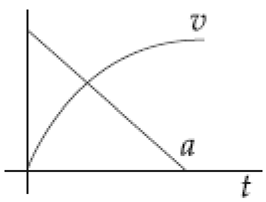
(4) $M^{-1} L^{-3} T^3 I$

2. Which of the following option correctly describes the variation of the speed v and acceleration 'a' of a point mass falling vertically in a viscous medium that applies a force $F = -kv$, where 'k' is a constant, on the body ? (Graphs are schematic and not drawn to scale)

(1) 

(2) 

(3) 

(4) 

3. A rocket is fired vertically from the earth with an acceleration of $2g$, where g is the gravitational acceleration. On an inclined plane inside the rocket, making an angle θ with the horizontal, a point object of mass m is kept. The minimum coefficient of friction $\mu_{\min}$ between the mass and the inclined surface such that the mass does not move is :

(1) $\tan\theta$

(2) $2\tan\theta$

(3) $3\tan\theta$

(4) $\tan 2\theta$

4. A car of weight W is on an inclined road that rises by 100 m over a distance of 1 km and applies a constant frictional force $\frac{W}{20}$ on the car. While moving uphill on the road at a speed of $10\ ms^{-1}$, the car needs power P. If it needs power $\frac{P}{2}$ while moving downhill at speed v then value of v is :

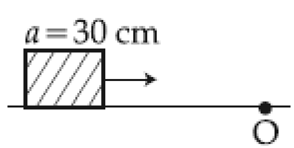
(1) $20\ ms^{-1}$

(2) $15\ ms^{-1}$

(3) $10\ ms^{-1}$

(4) $5\ ms^{-1}$

5. A cubical block of side 30 cm is moving with velocity $2\ ms^{-1}$ on a smooth horizontal surface. The surface has a bump at a point O as shown in figure. The angular velocity (in rad/s) of the block immediately after it hits the bump, is :



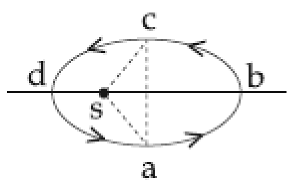
(1) 5.0

(2) 6.7

(3) 9.4

(4) 13.3

6. Figure shows elliptical path abcd of a planet around the sun S such that the area of triangle csa is $\frac{1}{4}$ the area of the ellipse. (See figure) With db as the semimajor axis, and ca as the semi-minor axis. If t_1 is the time taken for planet to go over path abc and t_2 for path taken over cda then :



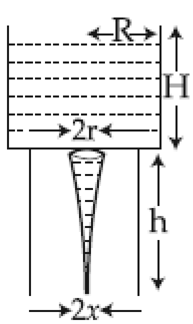
(1) $t_1 = t_2$

(2) $t_1 = 2t_2$

(3) $t_1 = 3t_2$

(4) $t_1 = 4t_2$

7.



Consider a water jar of radius R that has water filled up to height H and is kept on a stand of height h (see figure). Through a hole of radius r (r << R) at its bottom, the water leaks out and the stream of water coming down towards the ground has a shape like a funnel as shown in the figure. If the radius of the cross-section of water stream when it hits the ground is x. Then :

(1) $x = r\left(\frac{H}{H+h}\right)$

(2) $x = r\left(\frac{H}{H+h}\right)^{\frac{1}{2}}$

(3) $x = r\left(\frac{H}{H+h}\right)^{\frac{1}{4}}$

(4) $x = r\left(\frac{H}{H+h}\right)^{2}$

8. 200 g water is heated from 40 C to 60 C. Ignoring the slight expansion of water, the change in its internal energy is close to (Given specific heat of water=4184 J/kg/K) :

(1) 8.4 kJ

(2) 4.2 kJ

(3) 16.7 kJ

(4) 167.4 kJ

9. The ratio of work done by an ideal monoatomic gas to the heat supplied to it in an isobaric process is :

(1) $\frac{3}{5}$

(2) $\frac{2}{3}$

(3) $\frac{3}{2}$

(4) $\frac{2}{5}$

10. Two particles are performing simple harmonic motion in a straight line about the same equilibrium point. The amplitude and time period for both particles are same and equal to A and T, respectively. At time $t = 0$ one particle has displacement A while the other one has displacement $\frac{-A}{2}$ and they are moving towards each other. If they cross each other at time t, then t is :

(1) $\frac{T}{6}$

(2) $\frac{5T}{6}$

(3) $\frac{T}{3}$

(4) $\frac{T}{2}$

11. Two engines pass each other moving in opposite directions with uniform speed of 30 m/s. One of them is blowing a whistle of frequency 540 Hz. Calculate the frequency heard by driver of second engine before they pass each other. Speed of sound is 330 m/sec :

(1) 450 Hz

(2) 540 Hz

(3) 648 Hz

(4) 270 Hz

12. The potential (in volts) of a charge distribution is given by

$V(z) = 30 - 5z^2$ for $|z| \le 1\,\text{m}$

$V(z) = 35 - 10|z|$ for $|z| \ge 1\,\text{m}$.

V(z) does not depend on x and y. If this potential is generated by a constant charge per unit volume ρ_0 (in units of ϵ_0) which is spread over a certain region, then choose the correct statement.

(1) $\rho_0 = 10 \epsilon_0$ for $|z| \le 1$ m and $\rho_0 = 0$ elsewhere

(2) $\rho_0 = 20 \epsilon_0$ in the entire region

(3) $\rho_0 = 40 \epsilon_0$ in the entire region

(4) $\rho_0 = 20 \epsilon_0$ for $|z| \le 1$ m and $\rho_0 = 0$ elsewhere

13. Three capacitors each of 4 μF are to be connected in such a way that the effective capacitance is 6 μF. This can be done by connecting them :

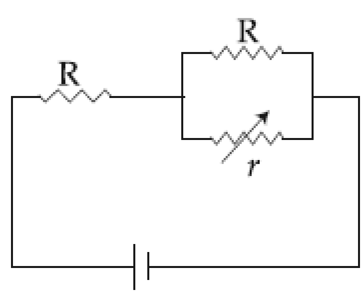
(1) all in series

(2) two in series and one in parallel

(3) all in parallel

(4) two in parallel and one in series

14.



In the circuit shown, the resistance r is a variable resistance. If for $r = f$ R, the heat generation in r is maximum then the value of f is :

(1) $\frac{1}{4}$

(2) $\frac{1}{2}$

(3) $\frac{3}{4}$

(4) 1

15. A magnetic dipole is acted upon by two magnetic fields which are inclined to each other at an angle of 75 . One of the fields has a magnitude of 15 mT. The dipole attains stable equilibrium at an angle of 30 with this field. The magnitude of the other field (in mT) is close to :

(1) 11

(2) 36

(3) 1

(4) 1060

16. A 50 Ω resistance is connected to a battery of 5 V. A galvanometer of resistance 100 Ω is to be used as an ammeter to measure current through the resistance, for this a resistance r_s is connected to the galvanometer. Which of the following connections

should be employed if the measured current is within 1% of the current without the ammeter in the circuit ?

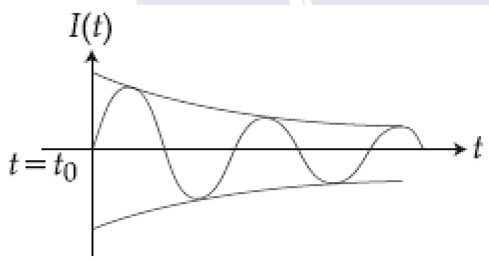
(1) r_s=0.5 Ω in parallel with the galvanometer

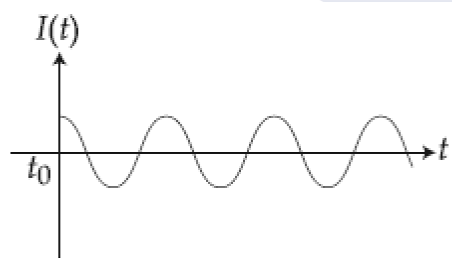
(2) r_s=0.5 Ω in series with the galvanometer

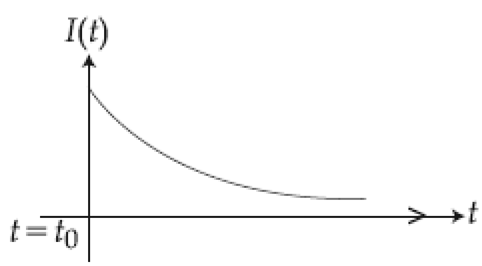
(3) r_s=1 Ω in series with the galvanometer

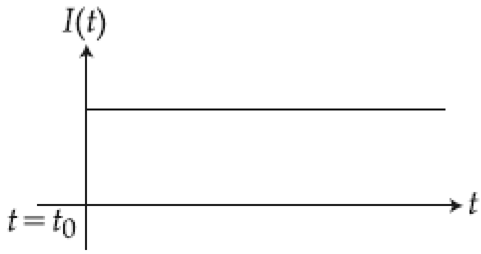
(4) r_s=1 Ω in parallel with the galvanometer

17. A series *LR* circuit is connected to a voltage source with $V(t) = V_0 \sin \Omega t$. After very large time, current *I*(*t*) behaves as $\left(t_0 >> \frac{L}{R} \right)$:

(1) 

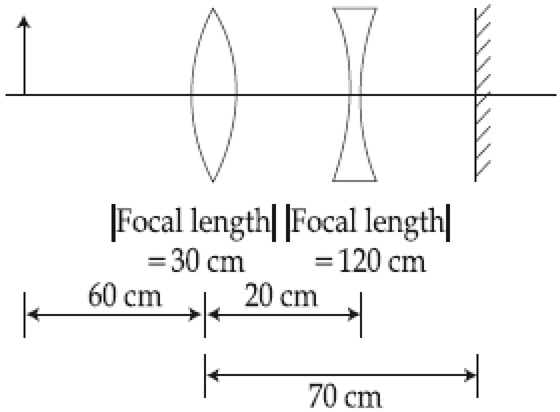
(2) 

(3) 

(4) 

18. Microwave oven acts on the principle of :
    (1) transferring electrons from lower to higher energy levels in water molecule
    (2) giving rotational energy to water molecules
    (3) giving vibrational energy to water molecules
    (4) giving translational energy to water molecules

19. A convex lens, of focal length 30 cm, a concave lens of focal length 120 cm, and a plane mirror are arranged as shown. For an object kept at a distance of 60 cm from the convex lens, the final image, formed by the combination, is a real image, at a distance of :



(1) 60 cm from the convex lens

(2) 60 cm from the concave lens

(3) 70 cm from the convex lens

(4) 70 cm from the concave lens

20. In Young's double slit experiment, the distance between slits and the screen is 1.0 m and monochromatic light of 600 nm is being used. A person standing near the slits is looking at the fringe pattern. When the separation between the slits is varied, the interference pattern disappears for a particular distance d_0 between the slits. If the angular resolution of the eye is $\frac{1^\circ}{60}$, the value of d_0 is close to :

(1) 1 mm

(2) 2 mm

(3) 4 mm

(4) 3 mm

21. When photons of wavelength λ_1 are incident on an isolated sphere, the corresponding stopping potential is found to be V. When photons of wavelength λ_2 are used, the corresponding stopping potential was thrice that of the above value. If light of wavelength λ_3 is used then find the stopping potential for this case :

(1) $\frac{hc}{e}\left[\frac{1}{\lambda_3}-\frac{1}{\lambda_2}-\frac{1}{\lambda_1}\right]$

(2) $\frac{hc}{e}\left[\frac{1}{\lambda_3}+\frac{1}{\lambda_2}-\frac{1}{\lambda_1}\right]$

(3) $\frac{hc}{e}\left[\frac{1}{\lambda_3}+\frac{1}{2\lambda_2}-\frac{3}{2\lambda_1}\right]$

(4) $\frac{hc}{e}\left[\frac{1}{\lambda_3}+\frac{1}{2\lambda_2}-\frac{1}{\lambda_1}\right]$

22. A hydrogen atom makes a transition from n = 2 to n = 1 and emits a photon. This photon strikes a doubly ionized lithium atom (z =3) in excited state and completely removes the orbiting

electron. The least quantum number for the excited state of the ion for the process is :

(1) 2

(2) 3

(3) 4

(4) 5

23. The truth table given in fig. represents :

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

(1) AND - Gate

(2) OR - Gate

(3) NAND - Gate

(4) NOR - Gate

24. An audio signal consists of two distinct sounds : one a human speech signal in the frequency band of 200 Hz to 2700 Hz,

while the other is a high frequency music signal in the frequency band of 10200 Hz to 15200 Hz. The ratio of the AM signal bandwidth required to send both the signals together to the AM signal bandwidth required to send just the human speech is :

(1) 3

(2) 5

(3) 6

(4) 2

25. A simple pendulum made of a bob of mass m and a metallic wire of negligible mass has time period 2 s at $T = 0$ C. If the temperature of the wire is increased and the corresponding change in its time period is plotted against its temperature, the resulting graph is a line of slope S. If the coefficient of linear expansion of metal is α then the value of S is :

(1) α

(2) $\frac{\alpha}{2}$

(3) 2α

(4) $\frac{1}{\alpha}$

26. A uniformly tapering conical wire is made from a material of Young's modulus Y and has a normal, unextended length L. The radii, at the upper and lower ends of this conical wire, have values R and $3R$, respectively. The upper end of the wire is fixed to a rigid support and a mass M is suspended from its lower end. The equilibrium extended length, of this wire, would equal :

(1) $L\left(1+\frac{2}{9}\frac{Mg}{\pi YR^2}\right)$

(2) $L\left(1+\frac{1}{3}\frac{Mg}{\pi YR^2}\right)$

(3) $L\left(1+\frac{1}{9}\frac{Mg}{\pi YR^2}\right)$

(4) $L\left(1+\frac{2}{3}\frac{Mg}{\pi YR^2}\right)$

27. To know the resistance G of a galvanometer by half deflection method, a battery of emf V_E and resistance R is used to deflect the galvanometer by angle θ. If a shunt of resistance S is needed to get half deflection then G, R and S are related by the equation:

(1) $2S(R+G)=RG$

(2) $S(R+G)=RG$

(3) $2S=G$

(4) $2G=S$

28. To find the focal length of a convex mirror, a student records the following data :

Object Pin	Convex Lens	Convex Mirror	Image Pin
22.2 cm	32.2 cm	45.8 cm	71.2 cm

The focal length of the convex lens is f_1 and that of mirror is f_2. Then taking index correction to be negligibly small, f_1 and f_2 are close to :

(1) $f_1 = 12.7$ cm $\quad f_2 = 7.8$ cm

(2) $f_1 = 7.8$ cm $\quad f_2 = 12.7$ cm

(3) $f_1 = 7.8$ cm $\quad f_2 = 25.4$ cm

(4) $f_1 = 15.6$ cm $\quad f_2 = 25.4$ cm

29. An experiment is performed to determine the I - V characteristics of a Zener diode, which has a protective resistance of R = 100 Ω, and a maximum power of dissipation rating of 1 W. The minimum voltage range of the DC source in the circuit is :

(1) 0 – 5 V

(2) 0 – 8 V

(3) 0 – 12 V

(4) 0 – 24 V

30. An unknown transistor needs to be identified as a *npn* or *pnp* type. A multimeter, with +ve and −ve terminals, is used to measure resistance between different terminals of transistor. If terminal 2 is the base of the transistor then which of the following is correct for a *pnp* transistor ?

(1) +ve terminal 1, −ve terminal 2, resistance high

(2) +ve terminal 2, −ve terminal 1, resistance high

(3) +ve terminal 3, −ve terminal 2, resistance high

(4) +ve terminal 2, −ve terminal 3, resistance low

1. Calculate the dimension of resistance,

$$[R]=\left[\frac{1}{\rho}\frac{L}{A}\right]$$

$$[\rho]=\frac{[L]}{[R][A]}$$

$$=\frac{[L]}{[V/I]\left[L^2\right]}$$

$$=\left[V^{-1}\right]\left[L^{-1}I\right]$$

Solve further to calculate the dimensions of conductivity.

$$[\rho]=[Q/W]\left[L^{-1}I\right]$$

$$=\left[IT/ML^2T^{-2}\right]\left[L^{-1}I\right]$$

$$=\left[M^{-1}L^{-3}T^3I^2\right]$$

2. Write the formula to calculate the force,

$$F=-kv$$

$$ma=-kv$$

$$m\frac{dv}{dt}=-kv$$

$$m\frac{dv}{v}=-kdt$$

Integrate on both sides of the equation.

$$m\int\frac{dv}{v}=-k\int dt$$

$$m\ln v=-kt+C$$

$$v=v_0e^{-mkt}$$

The formula for acceleration is given by,

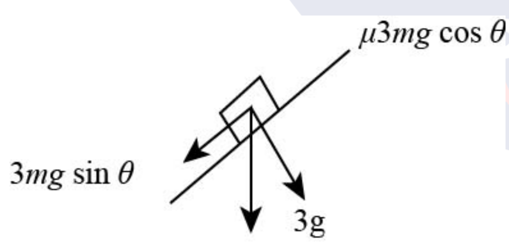
$$a=\frac{dv}{dt}$$

$$=-v_0mke^{-mkt}$$

This acceleration is represented graph (2).

3. All the forces acting on the block are labeled on the free body diagram of the block which is shown below,

Resolve the gravitational force into two components.



The net force on the block is given by,

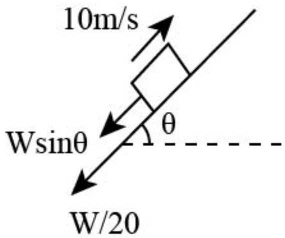
$$\Sigma F_{\text{block}}=0$$

$$3mg\sin\theta-3\mu mg\cos\theta=0$$

$$\mu\cos\theta=\sin\theta$$

$$\mu=\tan\theta$$

4. The car is inclined at a height of 100 m at a distance of 1 km on an inclined plane as shown below,



calculate the value of $\tan\theta$.

$$\tan\theta = \frac{100}{1000}$$

$$= \frac{1}{10}$$

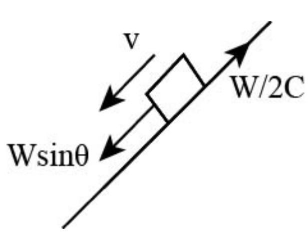
$$= \frac{1\Big/\sqrt{10^2+1^2}}{10\Big/\sqrt{10^2+1^2}}$$

Calculate the value of $\sin\theta$.

$$\sin\theta = \frac{1}{\sqrt{101}}$$

$$\sin\theta \approx \frac{1}{10}$$

When car moves downward,



The power of the system is given by,

$$P = F \times A$$

$$= \left(W \sin \theta + \frac{W}{20} \right) 10$$

$$= \left(\frac{W}{10} + \frac{W}{20} \right) 10$$

$$= \frac{3W}{2}$$

Divide both sides of the equation by 2.

$$\frac{P}{2} = \frac{3W}{4}$$

$$F_{\text{riction}} v = \frac{3W}{4}$$

$$\frac{W}{20} v = \frac{3W}{4}$$

$$v = 15 \, \text{m/s}$$

5. The moment of inertia of the system is given by,

$$I = m\left[\frac{R^2}{6} + \left(\frac{R}{\sqrt{2}} \right)^2 \right]$$

The angular momentum is expressed as,

$$L = I\omega$$

$$mvr = I\omega$$

$$\omega = \frac{m\left(v\frac{R}{2}\right)}{m\left[\frac{R^2}{6} + \left(\frac{R}{\sqrt{2}}\right)^2\right]}$$

$$= \frac{\frac{v}{2}}{\left[\frac{R}{6} + \frac{R}{2}\right]}$$

The angular speed is further calculated as,

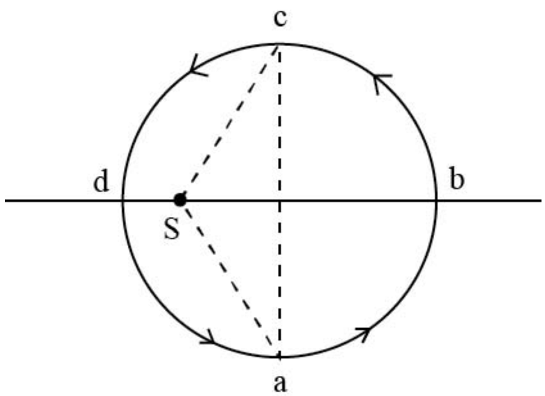
$$\omega = \frac{\frac{v}{2}}{\frac{4R}{6}}$$

$$= \frac{3v}{4R}$$

$$= \frac{3 \times 2}{4 \times 30 \times 10^{-2}}$$

$$= 5\,\text{m/s}$$

6. Consider the elliptical orbit as shown in the figure below.



Calculate the area of abca.

$$\text{Area}(\text{abca}) + \text{Area}(\text{sca}) = \text{Area}(\text{sabcs})$$

Calculate the area of adca.

$$\text{Area}(\text{adca}) - \text{Area}(\text{sca}) = \text{Area}(\text{sadcs})$$

The given condition is,

$$\text{Area}(\text{sca}) = \frac{1}{4}\text{Area}(\text{ellipse})$$

And

$$\text{Area}(\text{abca}) = \text{Area}(\text{adca})$$
$$= \frac{1}{2}\text{Area}(\text{ellipse})$$

So area of abca becomes,

$$\text{Area}(\text{abca}) = \text{Area}(\text{adca})$$
$$= 2\text{Area}(\text{sca})$$

Then,

$$\text{Area}(\text{abca})\left[1+\frac{1}{2}\right]=\text{Area}(\text{sabcs})$$

Area of adca becomes,

$$\text{Area}(\text{adca})\left[1-\frac{1}{2}\right]=\text{Area}(\text{sadcs})$$

Apply the Kepler's Law,

$t \propto \text{Area}$

$$\frac{t_1}{t_2}=\frac{1+\frac{1}{2}}{1-\frac{1}{2}}=3$$

$$t_1 = 3t_2$$

7. The energy equation is given by,

$$\frac{1}{2}\text{mv}_1^2 = \text{mgH}$$

$$\text{v}_1^2 = 2\text{gH}$$

The Bernoulli's theorem is stated as follows,

$$\frac{1}{2}\rho\text{v}_1^2 + \rho\text{gh} = \frac{1}{2}\rho\text{v}_2^2$$

$$\text{v}_1^2 + 2\text{gh} = \text{v}_2^2$$

$$\text{v}_2^2 = 2\text{gH} + 2\text{gh}$$

According to the equation of continuity,

$$A_1v_1 = A_2v_2$$

$$\pi r^2\sqrt{2gH} = \pi x^2 v_2$$

$$v_2 = \frac{r^2}{x^2}\sqrt{2gH}$$

$$v_2^2 = \frac{r^4(2gH)}{x^4}$$

Equate the two equation of v_2^2.

$$2gH + 2gh = \frac{r^4(2gH)}{x^4}$$

$$H + h = \frac{r^4}{x^4}H$$

$$\frac{r^4}{x^4} = \frac{H+h}{H}$$

$$x = r\left(\frac{H}{H+h}\right)^{\frac{1}{4}}$$

8. Since the volume of water doesn't change. Therefore, no work is done on or by the system. So the value of W is 0.

$W = 0$

According to the first law of thermodynamics,

$$Q = \Delta U + W$$

$$Q = \Delta U$$

$$\Delta U = mC_{\mathrm{p}}\Delta T$$

$$= 0.2 \times 4184 \times 20$$

Simplify the above equation and find the value of energy.

$$\Delta U = 16.7 \text{ kJ}$$

9. The formula for efficiency of heat engine is given by,

$$\eta = \frac{W}{Q}$$

$$= 1 - \frac{C_{\mathrm{v}}}{C_{\mathrm{p}}}$$

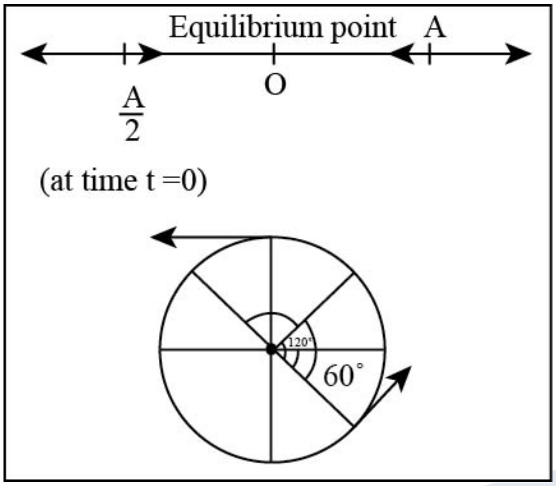
$$= \frac{C_{\mathrm{p}} - C_{\mathrm{v}}}{C_{\mathrm{p}}}$$

$$= \frac{R}{\frac{5R}{2}}$$

Hence, the efficiency of the heat engine is,

$$\eta = \frac{2}{5}$$

10. The path of the motion is shown in the figure below,



The value of angle covered to meet is,

$$60^\circ = \frac{\pi}{3}$$

In one time period, the angle covered is 2π .So if they cross each other at time t then,

$$t = \frac{\theta}{2\pi}T$$
$$= \frac{\pi T}{3 \times 2\pi}$$
$$= \frac{T}{6}$$

11. Write the expression for the Doppler effect,

$$f' = \left(\frac{v - v_0}{v + v_0}\right) f$$

$$= \left(\frac{330 + 30}{330 - 30}\right) \times 540$$

$$= 648 \text{ Hz}$$

12. For the value of $|z| \leq 1$ m

$$F = -\frac{dV}{dz}$$

$$= 10z$$

For the value of $|z| \geq 1$ m

$$F = -\frac{dV}{dz}$$

$$= 10$$

By Gauss's Law

$$\phi_e = \frac{q}{\varepsilon_0}$$

$$F \times A = \frac{\rho_0 A z}{\varepsilon_0}$$

$$F = \frac{\rho_0 z}{\varepsilon_0}$$

For the value of $|z| \leq 1$ m

$$10z = \frac{\rho_0 z}{\varepsilon_0}$$

$$\rho_0 = 10\varepsilon_0$$

For the value of $|z| \geq 1$ m

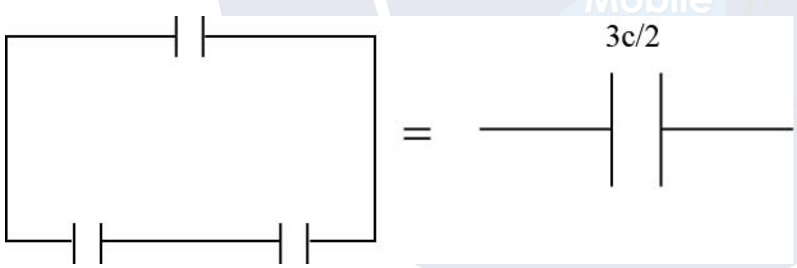
$$10 = \frac{\rho_0 z}{\varepsilon_0}$$

$$\rho_0 = \frac{10\varepsilon_0}{z}$$

For larger values of z, ρ_0 is zero.

Therefore, option (1) is partially correct.

13. Consider the diagram as shown below,



Calculate the equivalent capacitance as follows,

$$C_{eq} = 6$$

$$6 = 4 + 2$$

$$= 4 + \frac{4}{2}$$

Hence, the desired output is obtained when two capacitors are in series and one in parallel.

14. The maximum power is generated when the value of r is the equivalent resistance from r

The equivalent resistance from r is obtained by deactivating the source. From the terminals of r , the resistance offered is a parallel connection of R. Thus, the equivalent resistance is

$$r_{eq} = R \parallel R$$
$$= \frac{R}{2}$$

Hence, $f = \frac{1}{2}$

15. The formula to calculate the magnetic dipole moment is given by,

$$M = NIA\cos\theta$$
$$M \propto \cos\theta$$

When two magnetic fields are inclined at an angle of 75° the equilibrium will be at 30°.

$$\cos\theta = \cos\left(75^\circ - 30^\circ\right)$$
$$= \cos 45^\circ$$
$$= \frac{1}{\sqrt{2}}$$

If,

$$\frac{M_2}{M_1} = \frac{\cos\theta_2}{\cos\theta_1}$$
$$= \frac{\cos 30^\circ}{\cos 45^\circ}$$
$$= \frac{1/2}{1/\sqrt{2}}$$

Calculate the dipole moment in the second situation is,

$$M_2 = \frac{M_1}{\sqrt{2}}$$
$$= \frac{15}{\sqrt{2}}$$
$$= 10.6$$
$$\approx 11\ \text{mT}$$

16. The shunt should be connected in parallel in an ammeter.

According to the Ohm’s law,

$$I = \frac{V}{R}$$
$$= \frac{5}{50}$$
$$= 0.1\ \text{A}$$

When the galvanometer is connected in the circuit,

$$I' = 0.1(1 - .01)$$
$$= 0.099\ \text{A}$$

Since,

$$R_{\text{eq}} = 50 + \frac{100S}{100 + S}$$
$$\frac{5}{0.099} = 50 + \frac{100S}{100 + S}$$
$$\frac{100S}{100 + S} = \frac{5}{0.099} - 50$$
$$\frac{100S}{100 + S} = 50.505 - 50$$

Solve the equation further to calculate the value of S,

$$100S = 50.5 - 0.505S$$
$$100.505S = 50.5$$
$$S = 0.5$$

17. The current lags the voltage by some phase difference in RL circuit.

The formula for current is given by,

$$I = \frac{V_0}{R} \frac{1}{\sqrt{1 + \left(\omega \frac{L}{R}\right)^2}} \sin(\omega t - \phi)$$

The waveform of current will be sinusoidal.

18. The frequency of microwaves is synchronous with the frequency of vibrations in a water molecule. Microwave oven acts on the principle of giving vibration energy to water molecules.

19. The lens formula is given by,

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$$

Apply the lens formula for convex lens,

$$\frac{1}{30}=\frac{1}{v}+\frac{1}{60}$$

$$\frac{1}{v}=\frac{1}{60}$$

$$v=60\text{ cm}$$

Apply the lens formula for concave lens,

$$\frac{1}{-120}=\frac{1}{v}-\frac{1}{40}$$

$$\frac{1}{v}=\frac{1}{-120}+\frac{1}{40}$$

$$=\frac{1}{60}$$

$$v=60\text{ cm}$$

The reference point of measurement is from the lens. So, for the plane mirror, the image formed is calculated as,

$(50\text{ cm} - 60\text{ cm}) = 10\text{ cm}$.

The image formed by the plane mirror is now at a point 10 cm before it. Thus the image by the concave lens is obtained as by lens formula as

$$\frac{1}{-120} = \frac{1}{v} - \frac{1}{-50+10}$$
$$\frac{1}{-120} = \frac{1}{v} - \frac{1}{-40}$$
$$\frac{1}{v} = \frac{1}{-120} - \frac{1}{40}$$
$$v = -30\text{ cm}$$

The final image is formed by the convex lens. Use the lens formula for convex lens,

$$\frac{1}{30} = \frac{1}{v} - \frac{1}{-50}$$
$$\frac{1}{v} = \frac{1}{30} - \frac{1}{50}$$
$$v = 75\text{ cm}$$

Thus, the final image is formed at 75 cm from the convex lens.

20. The formula to calculate the angular resolution is given by,

$$\theta_r = \frac{\lambda}{d_0}$$

$$d_0 = \frac{60 \times 180 \times \lambda}{\pi}$$

$$= \frac{60 \times 180 \times 600 \times 10^{-9}}{\pi}$$

$$= 2 \times 10^{-3} \text{ m}$$

Hence, the value of d_0 is,

$$d_0 = 2 \text{ mm}$$

21. Consider the Einstein's photoelectric equation,

$$\frac{hc}{\lambda_1} = \frac{hc}{\lambda_0} + eV$$

$$\frac{hc}{\lambda_2} = \frac{hc}{\lambda_0} + eV$$

$$\frac{hc}{\lambda_3} = \frac{hc}{\lambda_0} + 3eV$$

Substitute the value in the above equation.

$$\frac{3}{2\lambda_1} - \frac{2}{2\lambda_2} = \frac{1}{\lambda_0}$$

The work function is given by,

$$eV' = \frac{hc}{\lambda_3} - \frac{3hc}{2\lambda_1} + \frac{hc}{2\lambda_2}$$

$$V' = \frac{hc}{e}\left(\frac{1}{\lambda_3} - \frac{3}{2\lambda_1} + \frac{1}{2\lambda_2}\right)$$

22. The hydrogen atom makes a transition from $n = 2$ to $n = 1$.

The wavelength is,

$$\lambda = Rcz^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

For hydrogen,

$$\lambda_{\mathrm{H}} = Rc\left[1 - \frac{1}{4}\right]$$

$$= \frac{3Rc}{4}$$

For ionized lithium,

$$\lambda_{\mathrm{Li}} = Rc(3)^2\left[\frac{1}{n^2}\right]$$

$$= \frac{9Rc}{n^2}$$

Thus,

$$\lambda_{\mathrm{H}} = \lambda_{\mathrm{Li}}$$

$$\frac{3Rc}{4} = \frac{9Rc}{n^2}$$

$$n^2 = 12$$

$$n = 2\sqrt{3}$$

The closest integer is 4.

23. The truth table for OR gate is shown below,

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

24. The bandwidth of AM signal is calculated as,

$$\frac{A_{\max} - M_{\min}}{A_{\min} - M_{\min}} = \frac{15200 - 200}{2700 - 200}$$

$$= \frac{15000}{2500}$$

$$= 6$$

25. The expression to calculate the time period at initial length is,

$$T_0 = 2\pi\sqrt{\frac{l_0}{g}}$$

The expression to calculate the time period expanded length is,

$$T = 2\pi\sqrt{\frac{l_0(1+\alpha T)}{g}}$$

Divide both the time periods

$$\frac{T_0}{T} = \frac{2\pi\sqrt{\frac{l_0}{g}}}{2\pi\sqrt{\frac{l_0(1+\alpha T)}{g}}}$$

$$T = T_0(1+\alpha T)^{\frac{1}{2}}$$

Use binomial expansion.

$$T = T_0\left(1+\frac{\alpha T}{2}\right)$$

$$T = 2\left(1+\frac{\alpha T}{2}\right)$$

$$T = 2+\alpha T$$

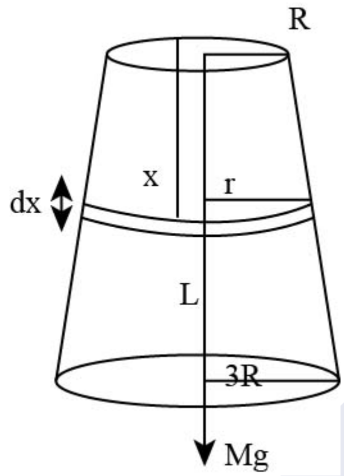
$$T - T_0 = \alpha T$$

If the coefficient of linear expansion is α then,

$$\frac{\Delta T}{T} = \frac{T\alpha}{T}$$

$$S = \alpha$$

26. The cross section of the wire is shown in figure below,



Consider a dx of radius r,

$$r = \frac{2R}{L}x + R$$

At equilibrium, the change in the length of the wire is calculated as,

$$\int_0^{\Delta L} dL = \int_0^L \frac{Mgdx}{\pi\left[\frac{2R}{L}x + R\right]^2 Y}$$

$$\Delta L = \frac{MgL}{3\pi R^2 Y}$$

The equilibrium extend length of the wire is calculated as,

$$L + \Delta L = L + \frac{MgL}{3\pi R^2 Y}$$

$$= L\left(1 + \frac{Mg}{3\pi R^2 Y}\right)$$

27. The formula to calculate the Current through galvanometer is given by,

$$I_G = \frac{V}{R}$$

When shunt resistance is connected parallel to galvanometer.

$$R_G = R + \frac{GS}{G+S}$$

the value of current becomes,

$$I = \frac{V}{R_g}$$

Also,

$$\frac{I_G}{2}G = \left(I - \frac{I_G}{2}\right)S$$

$$\frac{I_G}{2}(G+S) = IS$$

$$\frac{V}{2(R+G)} = \frac{V}{R + \frac{GS}{G+S}} \times \frac{S}{(G+S)}$$

$$(G+S)\left(R + \frac{GS}{G+S}\right) = 2(R+G)S$$

Further solve the equation.

$$R(G+S)+GS=2(R+G)S$$
$$RG+RS+GS=2RS+2GS$$
$$RG=S(R+G)$$

28. The mirror formula is given as,

$$\frac{1}{f_1}=\frac{1}{v}-\frac{1}{u}$$

$$\frac{1}{f_1}=\frac{1}{-10}-\frac{1}{39}$$

$$\frac{1}{f_1}=\frac{49}{390}$$

$$f_1=\frac{390}{49}$$

Simplify the above equation.

$$f_1=7.8\,\text{cm}$$

The focal length of the mirror is calculated as,

$$f_2=\frac{R}{2}$$
$$=\frac{71.2-45.8}{2}$$
$$=\frac{25.4}{2}$$
$$=12.7$$

Hence,

$f' = 7.96$

29. The minimum voltage range of the DC source is evaluated when power is 1W.

$$P = \frac{V^2}{R}$$

$$1 = \frac{V^2}{100}$$

$$V = 10$$

30. The terminal 1 is emitter which is highly doped.

The terminal 2 is collector which is moderately doped.

The terminal 2 is base which is lightly doped and very thin

The transistor has its emitter base junction forward biased.

Thus, for signal amplification, the resistance should be high.

For a pnp transistor the base should have negative potential.

The diagram depicts the explanation.